

## Active Galaxies at Milliarcsecond Resolution in the NOAO Deep Wide-Field Survey

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**Abstract.** We are using the NRAO VLBA at 5.0 GHz to image about 200 FIRST sources stronger than 10 mJy at 1.4 GHz in the NDWFS.

### 1. Motivation

Traditional continuum surveys using Very Long Baseline Interferometry (VLBI) have had limited astrophysical impact, because they suffer from a paucity of redshifts and from biases introduced by targeting bright and, often, flat-spectrum radio sources. To overcome these limitations, we are using the NRAO Very Long Baseline Array (VLBA) at 5.0 GHz to image about 200 compact FIRST sources stronger than 10 mJy at 1.4 GHz (White et al. 1997) in the NOAO Deep Wide-Field Survey (NDWFS). Optical identifications to 26 magnitudes (mag) are becoming available from the NDWFS (Jannuzi & Dey 1999) and spectroscopic follow-up has commenced for many of the FIRST sources.

### 2. Observations

Our VLBA (Napier et al. 1994) survey at 5.0 GHz uses phase referencing to reach about 100 FIRST sources in each of the Boötes and Cetus fields of the NDWFS. Each compact FIRST source was selected to have a largest angular size less than  $5''$ . The error ellipse for the *a priori* FIRST position typically had a FWHM of 850 milliarcseconds ( $4\sigma$ ). The phase referencing, in the nodding style, involved a switching time of 5 minutes and switching angles of  $2^\circ.5$  or less. Each FIRST source was observed with a total bandwidth of 64 MHz during six 80-second snapshots spread over time to enhance coverage in the  $(u, v)$  plane. Our VLBA survey is complete in the Boötes field and in progress in the Cetus field, with each field covering 9 square degrees.

### 3. Results

In the Boötes field, about one source in three was detected with the VLBA as stronger than 1.5-2.5 mJy ( $6\sigma$ ) at 2-milliarcsecond resolution. Most VLBA detections were unresolved but four apparent doubles were discovered. These

doubles are unlikely to be gravitational millilenses, as the upper limit at 95%-confidence to the expected lensing rate is about 1 lens per 430 sources (Wilkinson et al. 2001). Rather, these doubles might be Compact Symmetric Objects (CSOs), young and rare systems offering insights into evolutionary models for radio galaxies and strong tests of unified schemes (eg, Taylor et al. 2000). Follow-up VLBA observations are planned to test whether or not these doubles are indeed CSOs.

Optical identifications to 26 mag ( $5\sigma$ ) at  $2''$  resolution are becoming available for the Boötes field of the NDWFS. At these depths we expect that almost all FIRST sources will be identified, mostly with radio galaxies and quasars (Waddington et al. 2000). By contrast, less than a third of FIRST sources are identified to 22 mag in the Sloan Digital Sky Survey (Ivezić et al. 2002). Identifications are an essential prerequisite for redshifts. NDWFS identifications from early release data covering 1.4 square degrees are described in the figure for four VLBA detections.

Our VLBA images either locate the active nuclei within the optical hosts, or impose upper limits on emission from the active nuclei. We will constrain the spectral energy distributions of the active nuclei by combining the VLBA data with the photometric data from the NDWFS, from Chandra (C. Jones & S. Murray), and from SIRTf (P. Eisenhardt), as those data become available. The NDWFS and SIRTf data will also serve to constrain the galaxy cluster environments of the active nuclei.

The stronger VLBA detections can serve as in-beam phase calibrators for deep, wide-field VLBI imaging of the microJy sky in the Boötes field (de Vries et al. 2002; Morganti & Garrett 2002). Results from a 24-hour pilot study, using the VLBA and the NRAO Green Bank Telescope at 1.4 GHz, are presented in these Proceedings (Garrett, Wrobel, & Morganti 2004).

**Acknowledgments.** This work made use of images provided by the NDWFS, which is supported by NOAO. NOAO is operated by AURA, Inc., under a cooperative agreement with the NSF. NRAO is a facility of the NSF operated under cooperative agreement by AUI.

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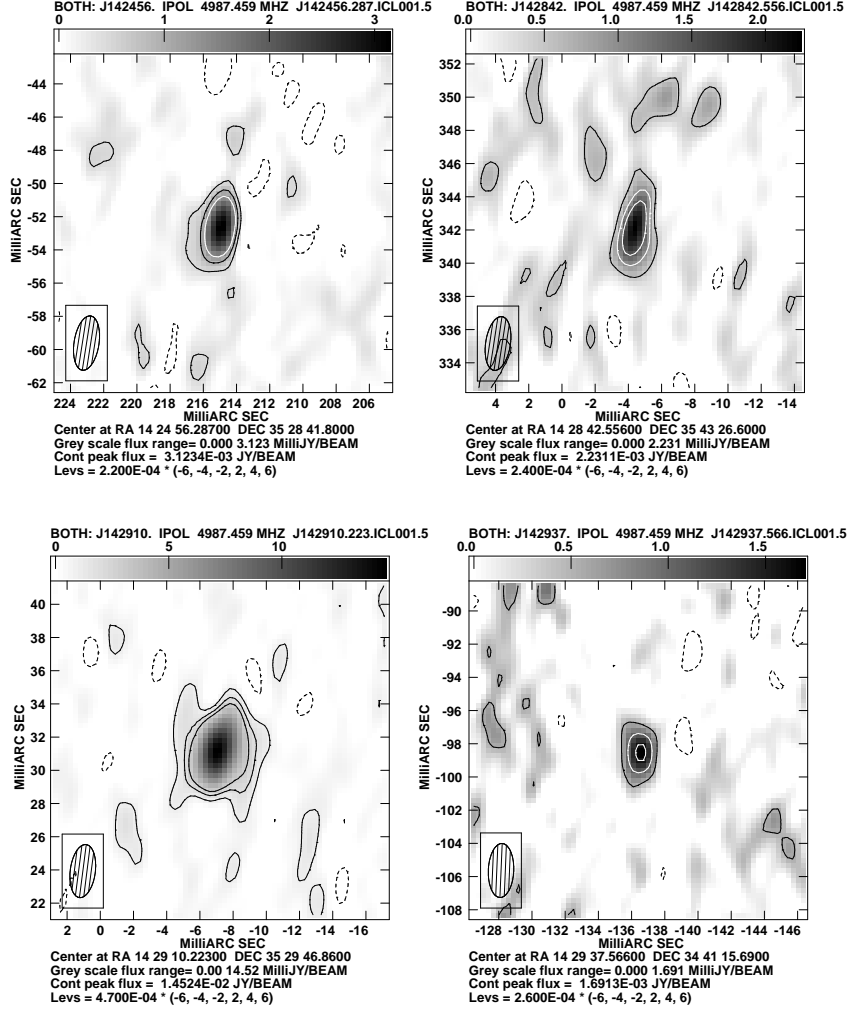


Figure 1. Images of Stokes I emission at 5.0 GHz for four VLBA detections with NDWFS identifications. Boxed ellipse shows the Gaussian restoring beam at FWHM. Contours are at  $\pm 2$ ,  $\pm 4$ , and  $\pm 6$  times the quoted rms noise levels. Angular offsets are relative to the quoted FIRST positions. *Top left:* J142456.287+352841.80,  $I \sim 19.8$  mag quasar. *Top right:* J142842.556+354326.60,  $I \sim 19.2$  mag galaxy. *Bottom left:* J142910.223+352946.86,  $I \sim 18.4$  mag quasar. *Bottom right:* J142937.566+344115.69,  $I \sim 21.5$  mag galaxy.